Spallation Neutron Source Project, Los Alamos National Laboratory

Cooling Pressure Drop Calculation For The Beam Stop in the Diagnostic Plate (D Plate) Beam Line.

Purpose:

The purpose of this calculation is to determine the coolant water pressure drop in the beam stop cooling system that exist between the supply and return manifolds attached to the Diagnostic Plate.

Assumptions:

- The maximum pressure drop across the beam stop cannot exceed about 30 psi per John Bernardin, who is the project leader for the linac cooling system.
- Snezana Konecni did the beam stop pressure drop calculations which is 30 psi according to Steve Ellis.
- The flow requirement for the Beam Stop is 10 GPM per Snezana Konecni. Steve Ellis thinks there is some conservatism in this figure.

Results:

With a flow rate of 10 gallons per minute, the final pressure drop across the beam stop system from supply manifold to return manifold is about 36 psi. This exceeds the pressure supplied by the water cooling system. I suggest that a boost pump be added to the supply line to increase the pressure.

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TechSource
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SNS Proj, Diagnostic Plate, Pressure Drop Across the Beam Stop

The beam stop pressure drop calculations have been done by Snezana Konecni (30psi). The only thing that is needed is to calculate the pressure drop in the feed and return lines from the water manifold through the beam stop and back to the water manifold. These lines have a globe valve and a flow meter which restricts the flow. In addition, there is a pressure drop generated when the flow is diverted from the main supply manifold and returned to the main return manifold from the beam stop. All of these effects are calculated in this calculation.

INPUTS:

$\rho := 999.552 \frac{kg}{m^3}$ Density of water

$\mu := 959 \cdot 10^{-6} \frac{N \cdot sec}{m^2}$ Viscosity of the water

$flow\_rate := 0.00063090 \cdot \frac{m^3}{s}$ Flow rate of the beam stop

$flex\_tube_{ID} := 0.02540000 \cdot m$

$pressure\_drop\_beam\_stop := 206843Pa$

$flex\_tube_{feed\_length} := 0.76200000 \cdot m$

$flex\_tube_{return\_length} := 1.27000000 \cdot m$

$manifold_{2inch\_Diam} := 0.05080000m$

$line_{1inch\_Diam} := 0.02540000m$

$Q_{beam\_stop} := 0.00063090 \frac{m^3}{sec}$

$Q_{2inch\_manifold} := 0.00082017 \frac{m^3}{sec}$

The heat transfer book that was used to calculate the pressure drops were: "Fundamentals of Heat and Mass Transfer" Second Edition, by Frank P. Incropera and David P. Dewitt.

Calculate the velocity of the fluid in the flex lines

$$flex_{area} := \frac{\pi \cdot flex\_tube_{ID}^2}{4}$$

$$velocity := \frac{flow\_rate}{flex_{area}}$$

$$velocity = 1.245 \frac{m}{s}$$

$$Re_D := \frac{\rho \cdot (velocity) \cdot flex\_tube_{ID}}{\mu}$$ **Reynolds number**

$$Re_D = 3.296 \times 10^4$$

$$friction_f := 0.184 \cdot Re_D^{-\left(\frac{1}{5}\right)}$$ Page 372, Eq 8.21,for a smooth surface, Incropera and Dewitt

$$friction_f = 0.023$$ Friction factor for smooth surfaces

I called the Crane Company for a Cv coefficient for a 1" globe valve and they said it was Cv=11.77 The relationship between K and Cv is: K=((29.9*D^2)/Cv)^2 where D is the diameter in inches (1"). This equation can be found on page 2-8 of the Crane Company technical paper 410. Therefore, K1 = 6.45

$$k1 := 6.45$$

$$h_{L1} := k1 \cdot \frac{velocity^2}{2}$$ $$h_{L1} = 5\,Sv$$

$$\Delta p_{across\_globe\_valve} := \rho \cdot h_{L1}$$

$$\Delta p_{across\_globe\_valve} = 4.997 \times 10^3\,Pa$$

The pressure drop across the supply and return tubes is:

$$head\_loss := friction_f \cdot \frac{\left(flex\_tube_{return\_length}\right) \cdot velocity^2}{flex\_tube_{ID} \cdot 2}$$

Mechanics of Fluids, Irving H Shames, Page 276, Eq 8.20

$$head\_loss = 0.89 \frac{m}{s^2} m$$

$$delta\_pressure_{feed\_tube} := \rho \cdot head\_loss \cdot 2$$

Multiplied by 2 to include the feed and the return paths.

$$delta\_pressure_{feed\_tube} = 1.78 \times 10^3 \, Pa$$

This is the pressure drop across the feed and return tube to the beam stop.

Calculate the pressure loss when the water to the beam stop flows from (seperates) the 2" supply manifold at a 45 degree angle. Refer to page 451, "Handbook of Hydraulic Resistance, 3rd Edition, IE Idelchik, author

$$\frac{Q_{beam\_stop}}{Q_{2inch\_manifold}} = 0.769$$

$$F_s := \frac{\pi \cdot \left(line_{1inch\_Diam}\right)^2}{4}$$

From table at the top on page 430 the ζ value is

$$\zeta_{cs} := 5.1$$

$$\zeta_s := \frac{\zeta_{cs}}{\left(\left(\frac{Q_{beam\_stop}}{Q_{2inch\_manifold}}\right)\right)^2}$$

Equation in middle of page 451

$$\zeta_s = 8.619$$

$$V_{water} := \frac{Q_{beam\_stop}}{F_s}$$

$$V_{water} = 1.245 \frac{m}{s}$$

$Head\_loss_{take\_off} := \zeta_s \cdot \frac{V_{water}^2}{2}$ Page 282, Eq:8.28 Mechanics of Fluids, Irving H. Shames. Second Ed.

$press_{loss\_take\_off} := \rho \cdot Head\_loss_{take\_off}$

$press_{loss\_take\_off} = 6.678 \times 10^3\,Pa$ $press_{loss\_take\_off} = 0.969\,psi$

Calculate the pressure loss when the water from the beam stop flows back (merged) into the 2" return manifold. Refer to page 430, "Handbook of Hydraulic Resistance, 3rd Edition, IE Idelchik, author

$$F_c := \frac{\pi \cdot \left(manifold_{2inch\_Diam}\right)^2}{4}$$

$$F_s := \frac{\pi \cdot \left(line_{1inch\_Diam}\right)^2}{4}$$

$$\frac{F_s}{F_c} = 0.25$$

$$\frac{Q_{beam\_stop}}{Q_{2inch\_manifold}} = 0.769$$

From table at the top on page 430 the ζ value is

$$\zeta_{cs} := 8.2$$

$$\zeta_s := \frac{\zeta_{cs}}{\left[\left(\frac{Q_{beam\_stop}}{Q_{2inch\_manifold}}\right) \cdot \left(\frac{F_c}{F_s}\right)\right]^2} \qquad \zeta_s = 0.866$$

$$V_{water} := \frac{Q_{beam\_stop}}{F_s}$$

$$V_{water} = 1.245\,\frac{m}{s}$$

$$Head\_loss_{merge} := \zeta_s \cdot \frac{V_{water}^2}{2}$$ Page 282, Eq:8.28 Mechanics of Fluids, Irving H. Shames. Second Ed.

$$pressure\_loss_{merge} := \rho \cdot Head\_loss_{merge}$$

$pressure\_loss_{merge} = 671.062\,Pa$ $pressure\_loss_{merge} = 0.097\,psi$

The pressure drop across the flow meter is typically 4 psi. This value is taken from "SPONSLER CO., INC. Catalog. Bulletin 5007 5/97

$$\Delta p_{flow\_meter} := 27579 \cdot Pa$$

Total pressure drop across the beam stop is:

$$\begin{aligned} total\_pressure\_drop := {} & delta\_pressure_{feed\_tube} + pressure\_drop\_beam\_stop \ldots \\ & + \Delta p_{across\_globe\_valve} + \Delta p_{flow\_meter} + press_{loss\_take\_off} \cdots \\ & + pressure\_loss_{merge} \end{aligned}$$

$total\_pressure\_drop = 2.485 \times 10^5\,Pa$

$\boxed{total\_pressure\_drop = 36.049\,psi}$

This is the total pressure drop across the beam stop from supply manifold to return manifold.

This pressure drop exceeds the supply pressure drop in the D Plate cooling system. Therefore, it is recommended that a booster pump be added to the system to meet this higher pressure drop.